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By

JOHN A. FOCHT

ENGINEERING RESEARCH SERIES NO. 27

Bureau of Engineering Research
Division of the Conservation and Development of the Natural Resources of Texas

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of democracy. . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar

A STUDY OF TESTS OF CYLINDERS AND CORES TAKEN FROM CONCRETE ROADS IN TEXAS DURING 1928

1. *Introduction.*—During the year of 1928, the testing laboratory for the Bureau of Engineering Research and the Texas State Highway Department tested approximately eight thousand concrete cylinders, and one thousand cores taken from concrete roads laid in Texas during that year. Feeling that there was valuable information contained in these data, the author undertook to combine these results so they would be of value to the practicing engineer.

2. *Acknowledgment.*—The author wishes to acknowledge with thanks the coöperation and assistance afforded him by the Engineer of Materials and Tests of the Texas State Highway Department, and the officials and workmen of the Bureau of Engineering Research. He is particularly indebted to Mr. J. W. Whitaker who patiently and diligently transcribed from the records of the laboratory all of the results of the tests included in this study.

3. *Sampling.*—It is well realized by every engineer that if the results of tests are to mean anything, the sample itself must be a fair average of the total. This is especially true of concrete. It is felt that sufficient care is not always taken in the field to have the concrete going into the cylinder truly representative of the concrete in the pavement. During the last few years we have had so much of the "Water Cement Ratio Theory" pumped into us that practically every engineer realizes that, when conditions remain constant, batches equal, etc., the batch with the least water produces concrete having the highest crushing strength. One engineer reports that he had an inspector on one of his jobs who was a firm believer in this theory, and put it into practice in this manner: when the time came to make a test cylinder, this enterprising young man would select the driest part of the driest batch of concrete with which to fill his mold. The crushing strengths of

these cylinders were high. As soon as this engineer discovered that his inspector was making the cylinders as outlined, he advised him that the average of the concrete, and not the best, was what was desired. The Engineer of Materials and Tests for the Texas State Highway Department has issued instructions recently taken from the A. S. T. M. Standards C 31–27. "Concrete for the test specimens shall be taken immediately after it has been placed in the work. All of the concrete for each sample shall be taken from one place. A sufficient number of samples, each large enough to make one test specimen, shall be taken at different points so that the test specimens made from them will give a fair average of the concrete." Each sample should be truly representative of the batch from which it is taken, and there should be enough batches sampled to represent an average of the concrete.

4. *Molding.*—It appears that some variation has existed in the molding of the cylinders. It is very essential that if uniform results are to be obtained, uniform methods must be employed in preparing the specimens; this has been proven in the laboratory. From the same batch of concrete, cylinders may be made having an appreciable increase in strength by increased rodding. About two years ago, one inspector told the author that he had found a way to get strong cylinders—he rodded them excessively. This man had stumbled on this fact in practical experience, and, in an effort to have the results of his job look good, he was putting it into practice. Other reports have been received indicating that the cylinders had received especial care in rodding and compacting the concrete. The instructions mentioned above cover the method of rodding the concrete. It has been discovered that one inspector who had been furnished with a standard bullet-pointed tamping bar was using the wrong end. Tin molds were being used on this job, and the inspector used the flat end of the tamping bar to keep from punching holes in the bottom of the mold.

There have been a number of cylinders which when broken showed a large stone or gravel near the center of the specimen. This often creates a weak place in the cylinder. One inspector is reported to have used special precautions to prevent this, and to help make a stronger cylinder. After the mold was completely filled with concrete, he would run the tamping bar through the center of the cylinder, and make several circular turns with the bar so as to force the stone from the center of the cylinder, and have only mortar in this critical section. Even with all of these special precautions that have been taken to produce high crushing strengths, there are occasional cylinders arriving at the laboratory that are "honeycombed," showing among other things, the lack of rodding.

5. *Molds.*—In the past, cylinders have been made in practically every kind of mold that would hold concrete. The instructions mentioned above and good practice require that the molds be of non-absorbent material, strong enough to hold their shape during the molding of the cylinder, and substantially water tight. It is essential that the molds be water tight; if, during the process of making the cylinder, some of the water escapes or is lost, the concrete in the cylinder does not have the same water cement ratio as that in the batch from which the sample was taken, and the results of the tests are misleading. In general, paper molds have not been satisfactory. This type of mold requires considerably more care in handling, if the cylinder made in it is equal to one made in the metal mold.

6. *Curing.*—It is felt that in most cases attempts have been made to cure the cylinders in the standard manner—damp sand or earth. A few instances have been reported where the inspector cured some of the cylinders in the water tank on the mixer. Most of the mixers are powered with gasoline engines, and these engines require a fairly large tank for cooling water. The temperature of this water is considerably above air temperature, and sometimes may be as high as 180 degrees Fahrenheit; and this warmer temperature hastens the hardening of the concrete.

7. *Shipment.*—Practically all of the cylinders are shipped by express, but the methods by which they are protected vary widely. Some come with only a sticker pasted on the side of the cylinder, and often the edges are chipped or broken in transit. Some are shipped in wooden crates which protect the ends of the cylinders, but do not prevent their drying out. Some are wrapped in cement or gunny sacks, and some are packed in boxes filled with wet sawdust. It can be seen that the cylinders reach the laboratory in widely varying degrees of dryness due to the method of shipment.

8. *Laboratory procedure.*—As soon as the cylinders are received at the laboratory, workmen smooth the rough ends by means of a hammer and chisel. The ends of some cylinders are satisfactory as they are, while others are so round the cylinder will not stand on end, but will fall over; some cylinders have the date of making and other data scratched on the ends which present a rough surface requiring considerable handwork preparatory to capping. In the past, practically all of the cylinders were capped with plaster of Paris, and most of the cylinders discussed in this study were capped with this material. The present practice at the laboratory is to cap the cylinder with neat cement. In the past, if the cylinder was fourteen days old, or older, it was capped as soon as received, and stored in air in the laboratory until it was twenty-eight days old, when it was crushed in the testing machine. If the cylinder was less than fourteen days old when arriving at the laboratory, it was stored in the moist air closet until it was fourteen days old; at this time it was removed from the moist air closet, capped, and stored in air with the older cylinders to await its testing at the age of twenty-eight days. In the past, cylinders reached the laboratory at all ages; and due to the various ages when taken from the wet earth cover, the various methods of protection while in transit, and the various lengths of time stored in the laboratory, they had widely varying percentages of moisture when tested.

Since it is almost impossible to obtain a uniformly dry condition, there is a wide variation in the strengths of supposedly dry cylinders. Due to these facts, the minimum strength specifications are required for cylinders tested in a moist condition. In order to conform to the standard practice, the method of handling and testing the cylinders has been changed. The instructions mentioned above provide that the cylinder be cured for fourteen days in damp sand, and at the end of the fourteenth day taken up, and forwarded to the laboratory in a moist condition. One week is allowed for transportation of the cylinder from the field to the laboratory. When the cylinder reaches the laboratory, the ends are smoothed and capped with neat cement. As soon as the cap has hardened, the cylinder is placed in the moist air closet, and kept there until it is twenty-eight days old, when it is taken out to be tested. Only a few minutes elapse between the time of leaving the moist air closet and the time of testing. The testing is done by means of a 300,000-pound compression machine utilizing a hemispherical bearing block. All of these specimens have been tested by one man, who has been testing all of the cylinders for the Bureau for the past fourteen years.

The cores have been given a slightly different treatment. Several weeks after the laying of the last concrete, the core drill is sent to the job, and cores taken of the completed pavement. The cores are a check on the thickness of the completed road, and the quality of the concrete going into the pavement. Due to the very nature of things, the cores are not the same age, for the youngest core comes from the pavement that was laid last. Usually this age is about thirty days, while in one case it was only nineteen days. The oldest core dates back to the beginning of the job, and the intermediate ones vary in between. The oldest core represented in this study is three hundred and fifty days.

As soon as the cores arrive at the laboratory, they are measured for depth and diameter, and the areas calculated.

The end next to the subgrade is smoothed by means of a hammer and chisel; this treatment is exactly the same as that given the rough ends of the cylinders. In the past, this rough end has been capped with neat cement mortar, and the specimen placed in the moist air closet for one week to allow the cement cap to harden. At the end of this week the core was removed from the moist air closet, and a plaster of Paris cap put on both ends. The core was then stored in air in the laboratory for several days—usually from three to eight—and then crushed. No correction factor was applied to obtain a standard relation of height to diameter, or for difference in age. In order to obtain more uniform results, the present procedure is as follows: after the rough end of the core has been smoothed, as noted above, both ends are capped with neat cement, and the core is completely submerged in water for one week. At the end of this week the core is removed from the water, and tested while wet. The crushing strength is corrected for h/d according to U. S. D. A. Bulletin 1216, page 35. No correction is made for difference in age.

9. *Data for curves.*—The data for the curves were taken from the records of the testing laboratory for the Bureau of Engineering Research and the Texas State Highway Department. Practically all of the cylinders were twenty-eight days old, and on only one curve were results of cylinders more than thirty-three days old used; the oldest on this curve was forty-five days. When a job had only three or four old cylinders, these results were omitted, but when the majority of the cylinders were old, the whole job was discarded. All of the cylinders were standard 6″ x 12″.

Even though there is considerable variation in the ages of the cores when tested, no correction was applied for this difference. There are several variables affecting the strength of the concrete pavement over which there was no control, such as materials, season of the year, atmospheric conditions, etc. Cement from several plants, and fine and coarse aggregate from a large number of sources with varying properties, were used in the making of the concrete. Some of the pavements were laid during the fall and winter months, and the cores taken in the spring. This pavement had been exposed to the lower temperatures of the winter months. Other pavements were laid during the spring and summer, and the cores were taken in the late summer or early fall. This pavement had the advantage of the warmer temperatures. The State of Texas is so large that it experiences almost all varieties of climate and atmospheric conditions, varying from semi-tropical to temperate climate, and humid to semi-arid atmosphere; there are sections where the air is comparatively still, and others where it is exceedingly windy. Due to the fact that these factors exist in various combinations it is practically impossible to make corrections for the variations in age of the cores in this study.

Correction was applied for the relation of height to diameter. The area of each core, and not the diameter was given in the records; from this area the diameter was obtained. The height of each core was given; and with these two relations for each core, h/d was calculated. Given this ratio of h/d, the table for correcting the actual crushing strengths of concrete specimens having varying relations of h/d, as found in the revised edition of U. S. D. A. Bulletin 1216, was entered and the percentage of the actual crushing strength obtained. The actual crushing strength was multiplied by this factor, which gives the corrected crushing strength. It is this corrected strength that is used in plotting the accompanying curves.

The curves are plotted with the date the concrete is placed as abscissa, and the crushing strength in pounds per square inch as ordinate. There is a dotted line indicating the average of the cylinders for short periods of time, usually not exceeding ten days, while the results of the individual cores are connected by a solid line. A few jobs reported special curing conditions, and each is noted and recorded by a symbol. These data represent twenty-three different Federal Aid projects covering practically the entire State of Texas. As one will realize, there were cores tested during the early part of 1928 taken from projects laid during 1927, and there were projects just being completed, and some just being started in 1928 that were not cored until 1929. These data are naturally overlapping, and there are a few projects in the State which were partially completed and on which some tests were made during parts of 1928 which do not appear in this study.

The majority of the mixes reported were 1–2–3 1/2 measured by volume; there were some minor variations such as 1–1.88–3.3, 1–2–3 2/7, 1–2.3–3.26, 1–2.27–3.15, but no correction was applied for these variations. No notes were found that would indicate that any cylinders were taken from a water cement ratio job. The slump of the concrete varied from one-half to two inches.

The Texas State Highway Department specifications require that cylinders made of concrete going into pavement have a minimum crushing strength of three thousand pounds per square inch at the age of twenty-eight days.

10. *Curves.*—An examination of the curves reveals that, when based on the results of the cylinders, the curves may be divided into five groups:

a. The average of the cylinders is constant, and the curve is a horizontal line for the entire job.
b. The average of the cylinders shows an increase in strength as the job progresses.
c. The average of the cylinders shows a decrease in strength as the job progresses.
d. The average of the cylinders shows an increase in strength during the first part of the job, and a decrease in strength during the latter part of the job.
e. The average of the cylinders shows a decrease in strength during the first part of the job, and an increase in strength during the latter part of the job.

Curves 1, 2, 3, and 5 are typical of group *a*.
Curves, 6, 8, 9, 10, and 11 are typical of group *b*.
Curves 20 and 21 are typical of group *c*.
Curves 13, 14, 15, 16, 17, 18, and 19 are typical of group *d*.
Curves 7 and 23 are typical of group *e*.

Some of these curves are comparatively short, and, consequently, do not have time to develop the marked characteristics that some of the longer curves have. Group (d) has more curves than any of the other groups, and most of these curves are the longer ones which indicates that the job has been of sufficient duration to develop this marked characteristic. Groups (a) and (b) have several typical curves, but groups (c) and (e) do not have a strong representation. The curves in these last two groups are short, and if the job had lasted longer these curves might have taken a different trend.

A general inspection of all of the curves reveals the fact that there is a wide variation in the results obtained on practically all of the jobs. This seems to indicate a lack of uniformity somewhere on the job. It is felt that all of this variation is not to be found in the quality of the concrete going into the pavement, but that a large part of this variation is to be found in the cylinders themselves.

It is gathered from the curves that the strength of concrete laid during the summer months is only slightly less than that laid during the fall and spring. It is difficult to draw any conclusions about the concrete laid during the winter months on account of the mild winter weather in certain sections of Texas. Several of the jobs that were laid during the winter months are in that section of Texas where the winters are extremely mild, and where frost rarely comes. A few jobs occur in central or north Texas counties where the temperatures go below freezing almost every night during January and February. In this section of the State two jobs were shut down during the coldest part of the winter, while other jobs were not started until after the severest part of the winter was past. On those jobs where concrete was laid during the winter, the cylinders are considerably weaker, and the variation between individual cylinders is more than that at any other season.

It will be noticed on curve 4 that the average of the cylinders fluctuates up and down. For some reason or other all of the cylinders did not reach the laboratory so they could be tested at the age of twenty-eight days, but some were as much as forty-five days old when tested. Each crest in this average curve represents the older cylinders, and each sag represents the twenty-eight day old cylinders. This variation in age explains part of the variation in strength, and had all of the cylinders been tested when twenty-eight days old, apparently this would have been a very uniform job.

It is very interesting to note that when a job is shut down for a period of more than a week, the cylinders taken when starting the second time invariably have lower crushing strengths than those taken just before the mixer was shut down. Curves 9, 13, and 14 are typical of this fact. Two of these shut downs were in the winter, and one was in the middle of summer. Apparently, this is a result of disorganization rather than the time of the year.

It is interesting to note that on curve 8 the three cylinders taken each day have approximately the same crushing strengths. For each day, if one cylinder is low, all three are low, and if one cylinder is high, all three are high, comparatively speaking.

As previously mentioned there are several jobs on which the average strength curve shows an increase for a period, followed by a decrease. Of these curves showing this characteristic, the majority have the crest occurring in September, while there is a strong minority for April. It may be that there were more jobs under construction during the fall, which would give more jobs having this crest in September. These periods are the fall and spring of the year, and during these seasons there are not the larger variations of temperature experienced during the summer or winter. Apparently the average conditions found during these seasons are more favorable for stronger concrete.

On curve 11 there are the results from two mixers. This is apparent because on each day for about ten days there were cylinders reported from two widely separated sections on the road. It is interesting to note that the average of the cylinders from each mixer shows a decided increase in strength during this period, and that the curves almost coincide showing that about the same quality of concrete was being laid by each gang. This also indicates that local conditions became a little more favorable for higher strength concrete during this period.

Curves 14 and 15 represent jobs in a central Texas county; one job extends from December to August, and the other from March to June. It is interesting to notice that both of these curves show the average of the cylinders to increase for a period, and then to decrease in strength. Closer examination reveals that the crest or highest point on each curve of average strength occurs about May fifth. Local conditions played their part in these curves, as these are the only two curves showing the crest to be in May.

Curve 18 shows a peculiar drop in average strength in September. From June until September there is a gradual increase in the strength of the cylinders, and then in less than two weeks there is a drop in the average strength of approximately 1,200 pounds per square inch. This job was constructed in a south Texas county, and since the curves of jobs in counties in north Texas do not show this decided drop in strength, this big slump is not likely to be due to a "norther" or cold snap. Undoubtedly there were local conditions responsible for this enormous decrease.

On curve 9 there were four cylinders reported as being cured with sodium silicate during the latter part of September, while the main part of the job was water cured. These four cylinders are the lowest four cylinders during that period.

On curve 10 part of the cylinders plotted were cured with the Hunt Process, and the others were cured with water. During the first month of this job the Hunt Process was used entirely, and then for several days during May, cylinders cured with both the Hunt Process and water were reported. During the time when both methods of curing were used, the Hunt Process cured cylinders did not obtain strengths equal to the water cured cylinders, in fact there was not a single day during this period on which the highest Hunt Process cured cylinder was as strong as the lowest water cured cylinder.

On curve 12, the cylinders from December until about the first of May were water cured, and during this time there had been a gradual increase in strength of the cylinders as shown by the curve. Beginning about the first of May, and continuing through the remainder of the job, the majority of the cylinders were cured with sodium silicate, while a small minority were still cured with water. The water cured cylinders maintained the average crushing strength of approximately 5,000 pounds per square inch, while the sodium silicate cured cylinders began an immediate downward trend, and by the last of June, the average of these cylinders was slightly over 3,000 pounds per square inch. No curve of average strength was attempted during this period.

As is naturally expected the curves indicate that the cores increase in strength with age. On a good many of the curves showing the strength of the cores, there is a general upward trend of the curve from the last part of the job back towards the first part of the job indicating that the strength of the cores was increasing as the age of the cores increased. In some cases the curve of the core strength is almost horizontal. In most of these cases it is to be noted that the cylinders at the first part of the job are not as strong as they are at the last part of the job, which would indicate that the earlier concrete was weaker than the younger concrete, but due to the fact that the cores from the weaker concrete were older than those from the stronger concrete, they had increased in strength until they were about equal to the strengths of the younger cores. Curve 9 is the only one that shows the cores to decrease in strength with age, but one sees that the early cylinders are very, very poor. It is understood that considerable difficulty was experienced with aggregates during the first part of this particular job.

A good example of this increase in strength with age for the cores is shown on curve 11. During April and May there are two curves showing core strengths. This is explained by the fact that during the latter part of June, when the job was only about one-third completed, the core drill was in that vicinity, and cored the completed part of the road. When the job was completed in October, the entire road was cored, and some five or six of these cores overlap the cores taken in June. There is approximately five months difference in the time the cores were taken, which means that the cores taken in October are five months older than those taken in June, and these last cores show an increase in strength of some seven or eight hundred pounds per square inch over the first cores taken.

Curve 8 has a number of cores taken from concrete laid on the same days. These are from different experimental sections, and since the data were not available in the laboratory no further conclusions can be drawn.

Curve 10 has some cores from the pavement that was cured with the Hunt Process. These cores date from the beginning of the job up until about May 10. The cores taken from the pavement laid from May 18 to the end of the job were water cured. The average crushing strength of the Hunt Process cured cores is slightly higher than the average of the water cured cores—6,680 and 6,510 pounds per square inch respectively—but the Hunt Process cured cores have the advantage of age. Both curves show an upward trend as the cores become older, and taking this into consideration it is possible that the water cured cores of the same age as the Hunt Process cured cores would have a little higher crushing strength than the Hunt Process cured cores.

Curve 6 is the only curve on which the cores are lower than the cylinders. This particular curve has the highest average for the cylinders in this study, but the cores are about the average of all of the cores.

11. *Tables.*—Table I has been prepared showing the high, low, and average of the cylinders for each job, and the high, low, and average of the cores, with the additional columns for the youngest and oldest core tested for each job. From these data the average cylinder was found to have a crushing strength of 4,725 pounds per square inch,

and the average core a crushing strength of 5,850 pounds per square inch, after being corrected for h/d. The average core has a crushing strength 24% higher than the average cylinder. Even with the average of the cylinders nearly 60% above the minimum set by the State Highway Department, it is worthy of note that twelve of the twenty-three jobs represented in this study, have at least one cylinder that falls below the 3,000 pound minimum. One inspector, in discussing the results of the job with which he was connected, said that several of the lowest cylinders on his job were experimental cylinders, and did not truly represent the concrete as it was laid. This inspector said that one day a friendly argument arose as to the merit and value of curing, and in order to have proof for this argument two cylinders were made as nearly the same as possible. One was given the standard wet earth curing, while the other was placed on top of the pavement, and exposed to the sun and wind as soon as removed from the mold. The uncured cylinder had a crushing strength of 2,500 pounds per square inch, while its companion which had been given the standard curing had a crushing strength of over 4,500 pounds per square inch. It is possible that several of the low cylinders on the various jobs were made for experimental purposes, but the records in the laboratory did not have any such explanatory notes.

In the table, Job 10 has two lines for the cores. Part of the cores were taken from the Hunt Process cured pavement, and part from the water cured pavement. The bottom line is for the Hunt Process cured cores, and the top line is for the water cured cores.

In the table, Job 11 has two lines for the cores also. As mentioned above, this job was partially cored in June, and when the job was completed, cores were taken from the entire road. The top line represents the cores taken in October, while the bottom line represents the cores taken in June.

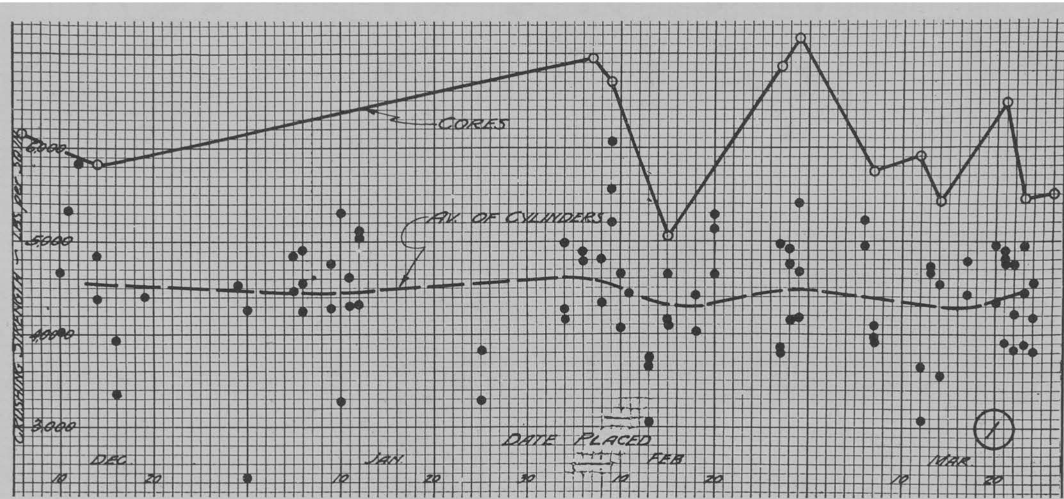
Table II has been prepared showing the percentage of the cylinders on each job falling within or without certain bands. The first part of this table was obtained by utilizing the average of the cylinders as found in the previous table, and counting the number of cylinders lying above a line that is 110% of the average of the cylinders, and the number of the cylinders below 90% of the average. The percentage of the cylinders above and below these lines is readily obtainable by dividing the number counted by the total number of cylinders on the job. This was repeated for 115% and 85%, 120% and 80%, and 125% and 75% of the average. It will be noticed that in most cases the percentages of the high and low cylinders are almost equal. In the second part of this table, the sum of the percentage of the high and low cylinders is subtracted from 100% giving the percentage falling within the desired limits. This table reveals that there is a big variation in the crushing strengths of the cylinders on the individual jobs. It will be noted that there is only one job on which 100% of the cylinders fall within the band of twenty-five percent either way from the average of the cylinders. It is a matter of interest that there is just one job on which 99% of the cylinders fall within this same band. Both of these jobs were supervised by the same engineer. To say the least of it, he was successful in obtaining the most uniform results from his cylinders of any engineer in Texas during 1928.

It is felt that if those in charge of concrete paving operations will closely follow the instructions mentioned above, which for the most part are excerpts from the A.S.T.M. Standards, the results of the tests of the cylinders will be much more uniform, more comparable, and well above the minimum requirements.

12. *Conclusions.*

1. Concrete going into Federal Aid paving projects in Texas during 1928 has a high crushing strength.
2. Cylinders made from concrete laid during the fall and spring have the highest crushing strengths.

3. Cylinders made from concrete laid during the winter months are not as strong as cylinders made from concrete laid during other seasons.
4. There is a wide variation on most jobs between the high and low cylinders.
5. It is necessary to follow standard sampling, molding, curing, shipping, and testing conditions in order to have uniform and comparable results.
6. The results of jobs reported seem to indicate that sodium silicate and Hunt Process cured cylinders do not have as high crushing strengths as water cured cylinders.
7. When a job is shut down for a week or more, the crushing strengths of the cylinders taken when starting the mixer the second time are lower than those of the cylinders taken just prior to the shutting down of the mixer.
8. The average cylinder in this study has a crushing strength of 4,725 pounds per square inch.
9. The average core in this study has a crushing strength of 5,850 pounds per square inch.
10. The cores show an increase in strength with an increase in age.


CORES
AV. OF CYLINDERS
6,000
5,000
4,000
3,000
CRUSHING STRENGTH – LBS. per SQ.IN.
DATE PLACED
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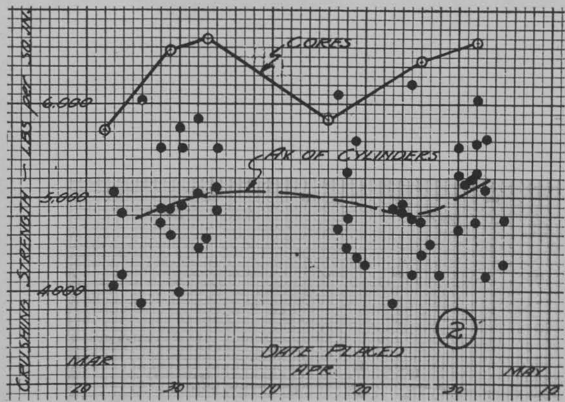
CORES
AV. OF CYLINDERS
CRUSHING STRENGTH — LBS. per SQ. IN.
6,000
5,000
4,000
DATE PLACED
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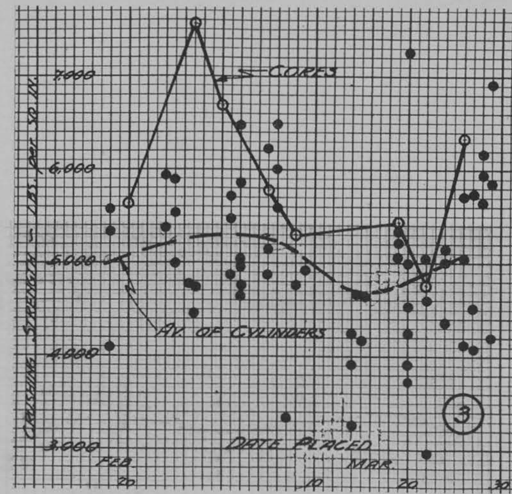
CORES
AV. OF CYLINDERS
CRUSHING STRENGTH — LBS. per SQ. IN.
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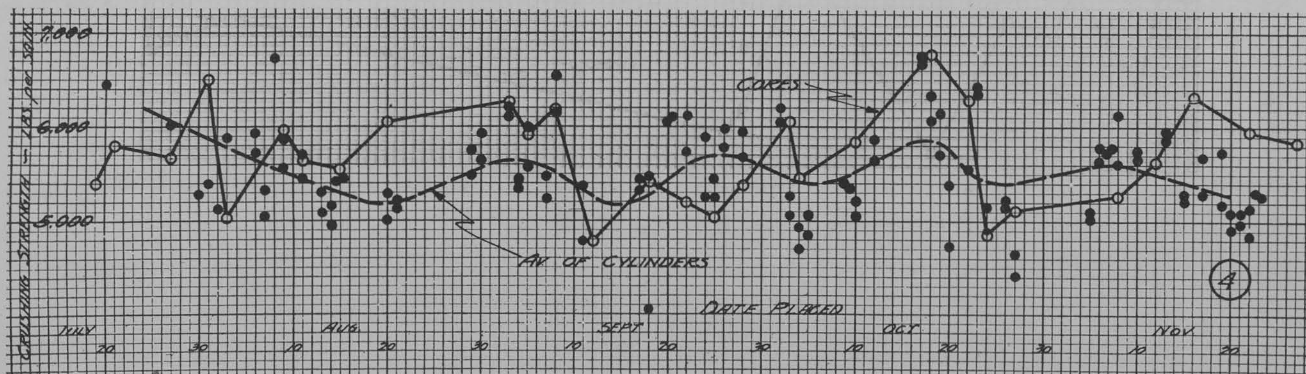
CORES
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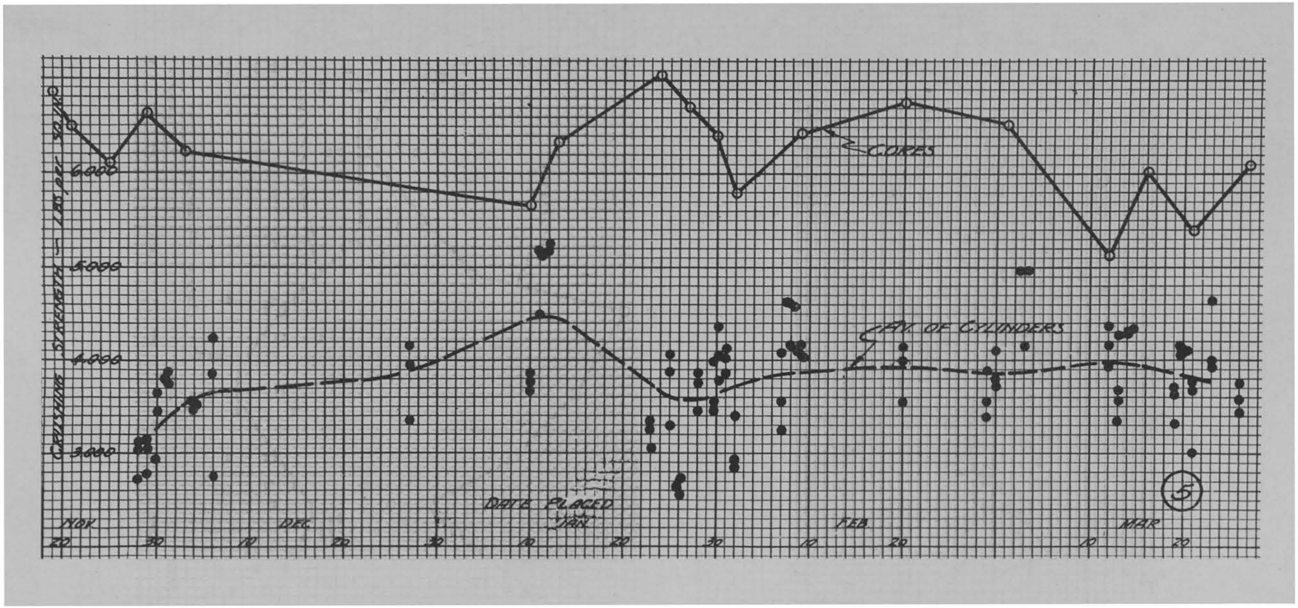
CRUSHING STRENGTH — LBS. PER SQ. IN.
6,000
5,000
4,000
3,000
CORES
AV. OF CYLINDERS
DATE PLACED
NOV.
DEC.
JAN.
FEB.
MAR.
20
30
10
20
30
10
20
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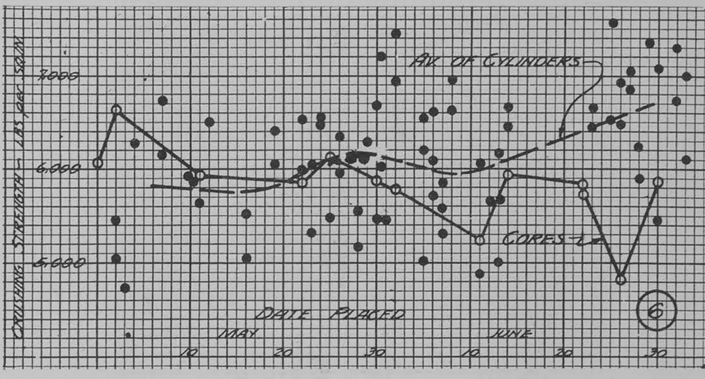
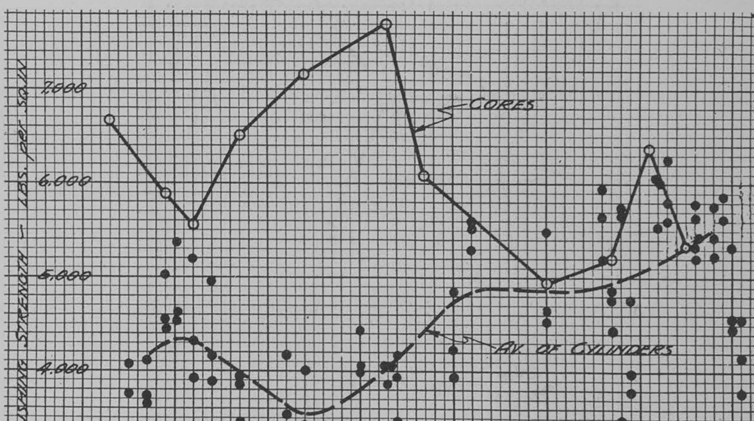
20
10
20
5



CRUSHING STRENGTH – LBS. per SQ.IN.
7,000
6,000
5,000
AV. OF CYLINDERS
CORES
DATE PLACED
MAY
JUNE
10
20
30
10
20
30
6



CRUSHING STRENGTH – LBS. per SQ.IN.
7,000
6,000
5,000
4,000
3,000
CORES
AV. OF CYLINDERS
DATE PLACED
MAR.
APR.
MAY
20
30
10
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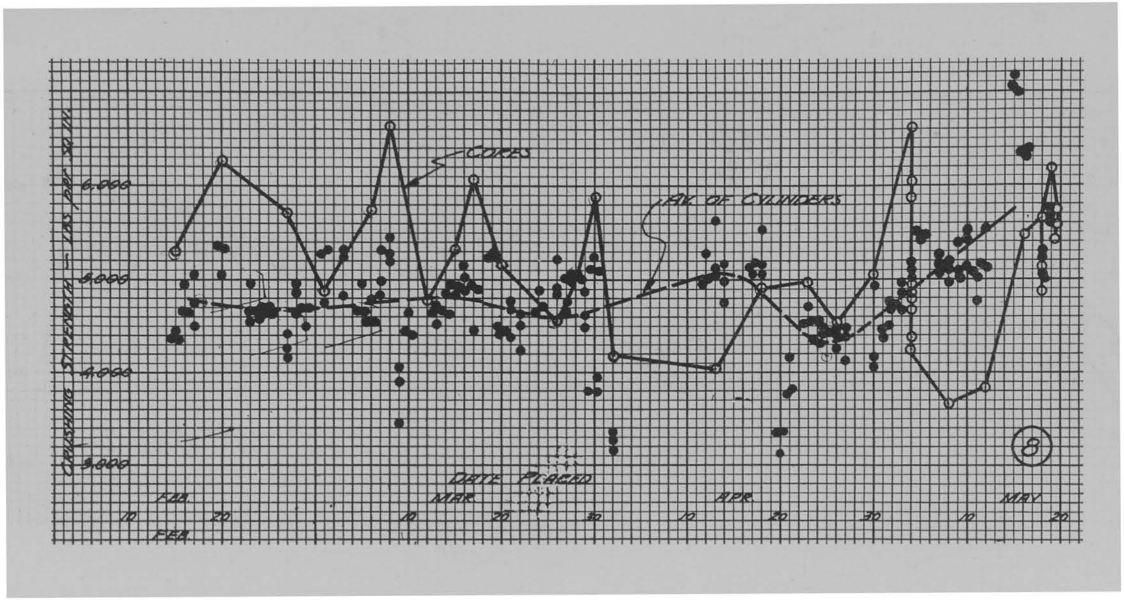
10
20
30
7



CORES
AV. OF CYLINDERS
CRUSHING STRENGTH — LBS. PER SQ. IN.
6,000
5,000
4,000
3,000
DATE PLACED
FEB.
MAR.
APR.
MAY
10
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10
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30
10
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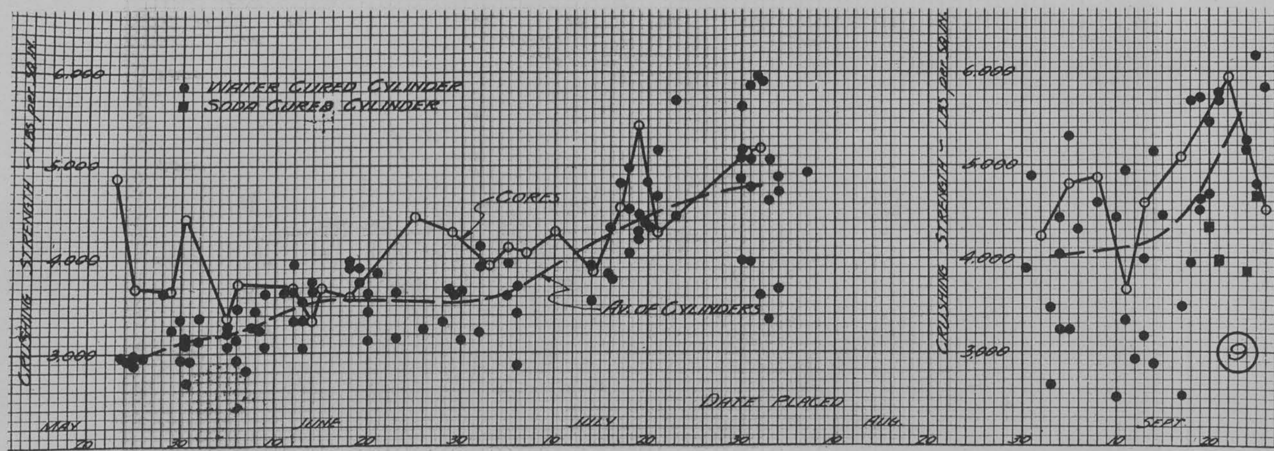
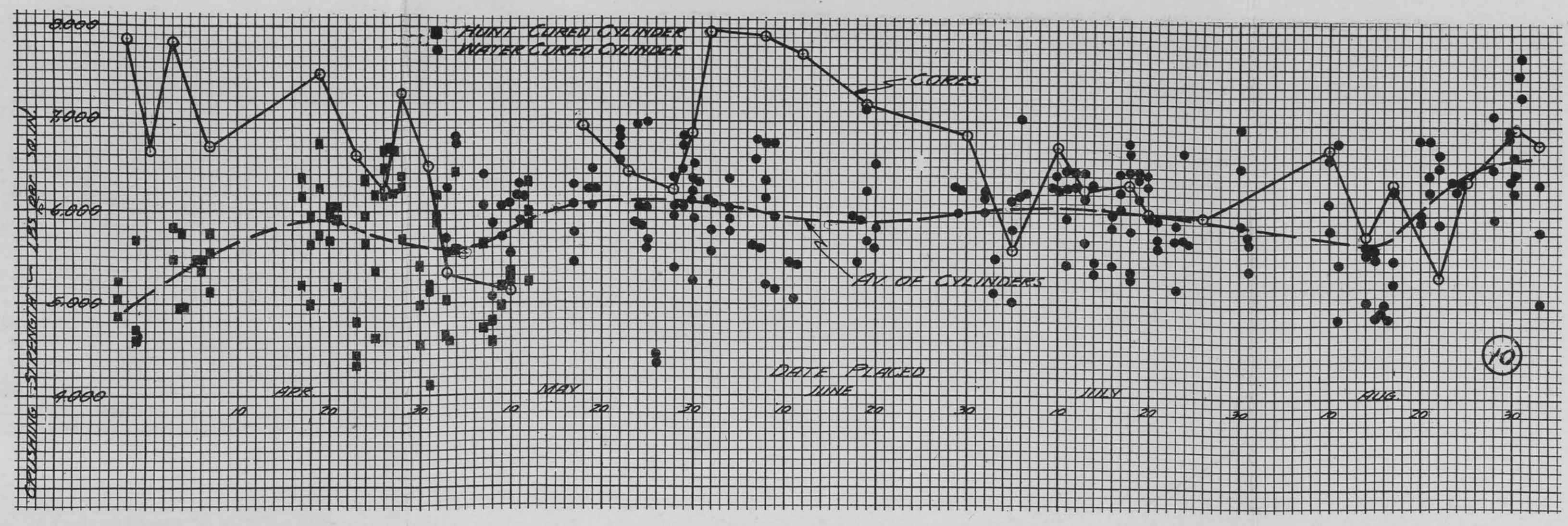
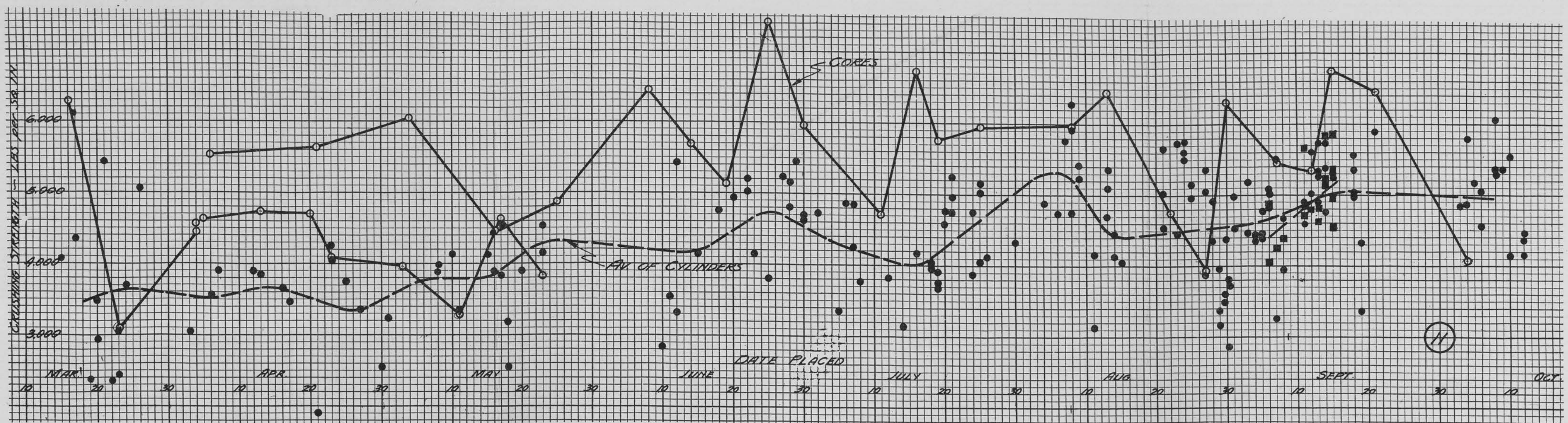
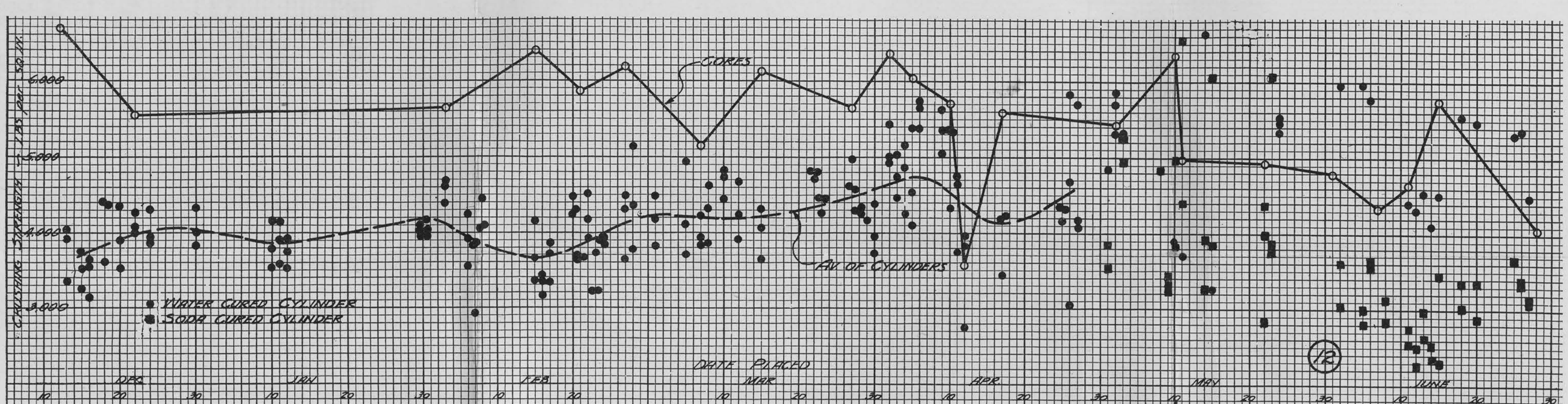
FEB.
8

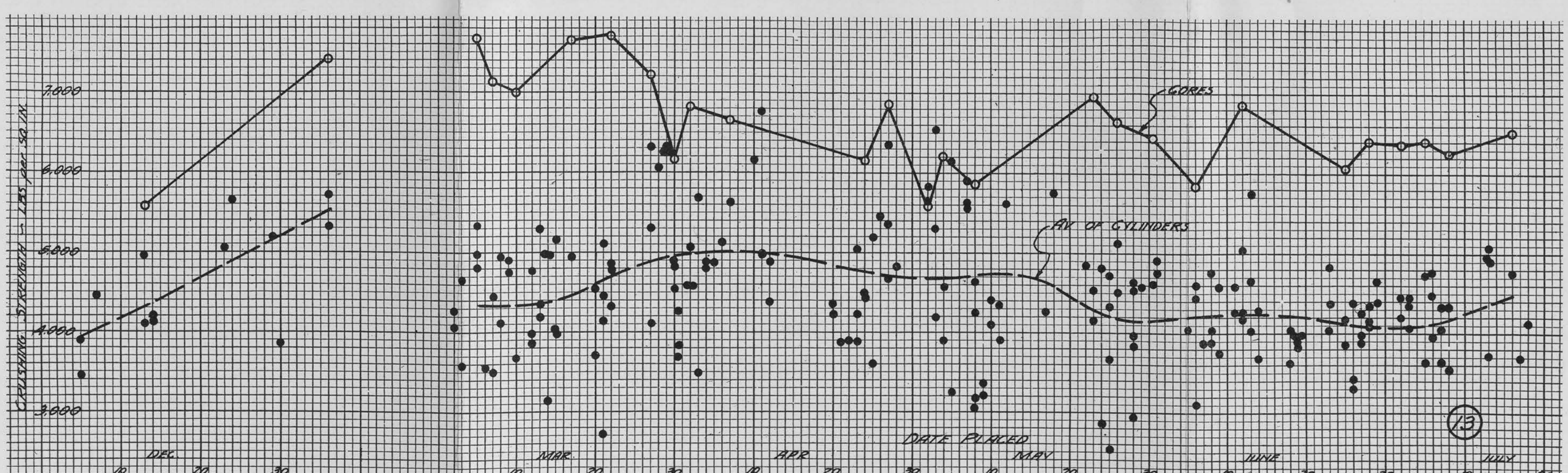


WATER CURED CYLINDER
SODA CURED CYLINDER
CRUSHING STRENGTH - LBS per SQ.IN.
6,000
5,000
4,000
3,000
CORES
AV. OF CYLINDERS
DATE PLACED
MAY
20
30
JUNE
10
20
30
JULY
10
20
30
AUG.
10
20
SEPT.
30
10
20
9


AIR CURED CYLINDER
WATER CURED CYLINDER
CORES
AV. OF CYLINDERS
CRUSHING STRENGTH – LBS. PER SQ. IN.
8,000
7,000
6,000
5,000
4,000
DATE PLACED
APR.
MAY
JUNE
JULY
AUG.
10


CORES
AV. OF CYLINDERS
CRUSHING STRENGTH – LBS. PER SQ. IN.
6,000
5,000
4,000
3,000
DATE PLACED
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
11


CORES
AV. OF CYLINDERS
WATER CURED CYLINDER
SODA CURED CYLINDER
CRUSHING STRENGTH – LBS. PER SQ. IN.
6,000
5,000
4,000
3,000
DATE PLACED
DEC.
JAN.
FEB.
MAR.
APR.
MAY
JUNE
12


CORES
AV. OF CYLINDERS
CRUSHING STRENGTH – LBS. PER SQ. IN.
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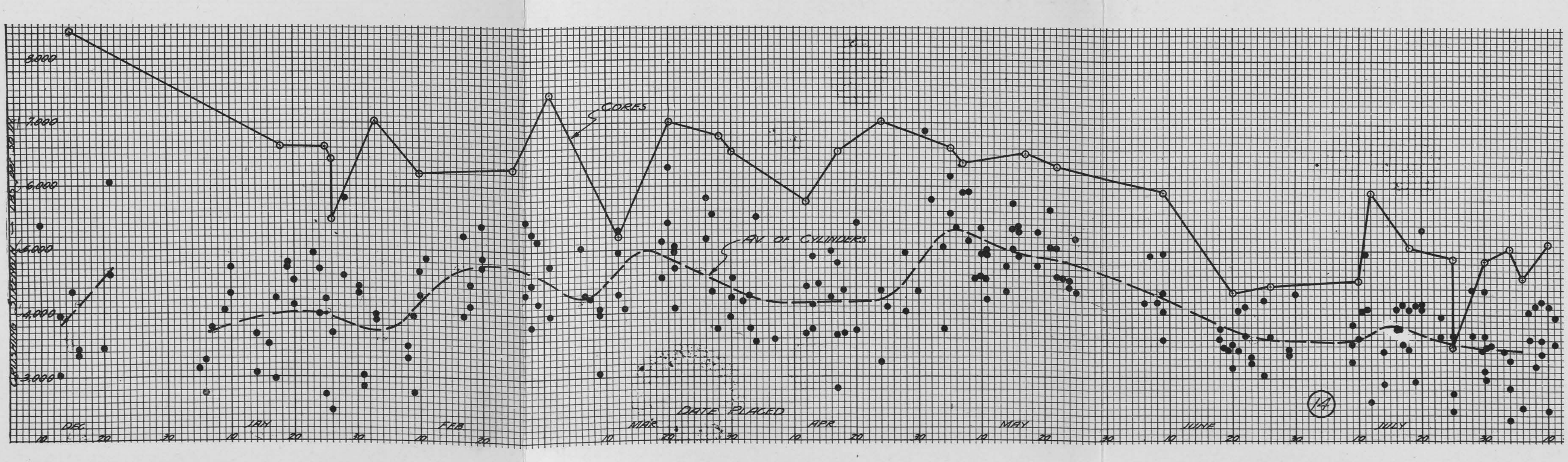
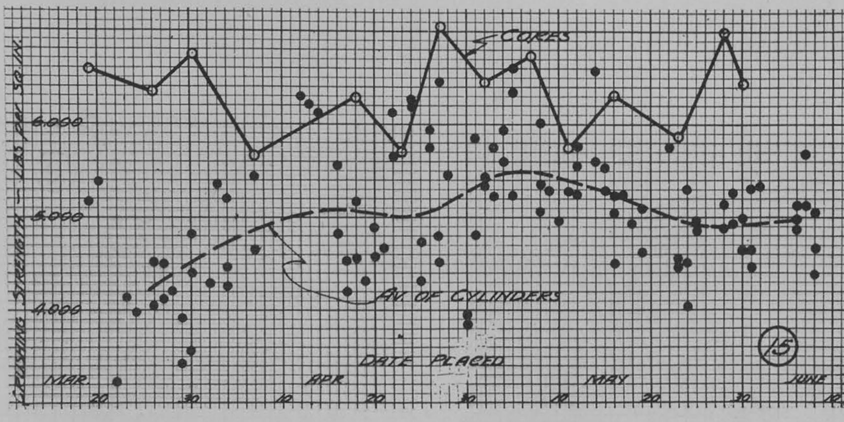
6,000
5,000
4,000
3,000
DATE PLACED
DEC.
MAR.
APR.
MAY
JUNE
JULY
13


CORES
AV. OF CYLINDERS
CRUSHING STRENGTH – LBS. PER SQ. IN.
8,000
7,000
6,000
5,000
4,000
3,000
DATE PLACED
DEC.
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
14


CORES
6,000
5,000
4,000
CRUSHING STRENGTH — LBS PER SQ. IN.
AV. OF CYLINDERS
DATE PLACED
15
MAR.
APR.
MAY
JUNE
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20
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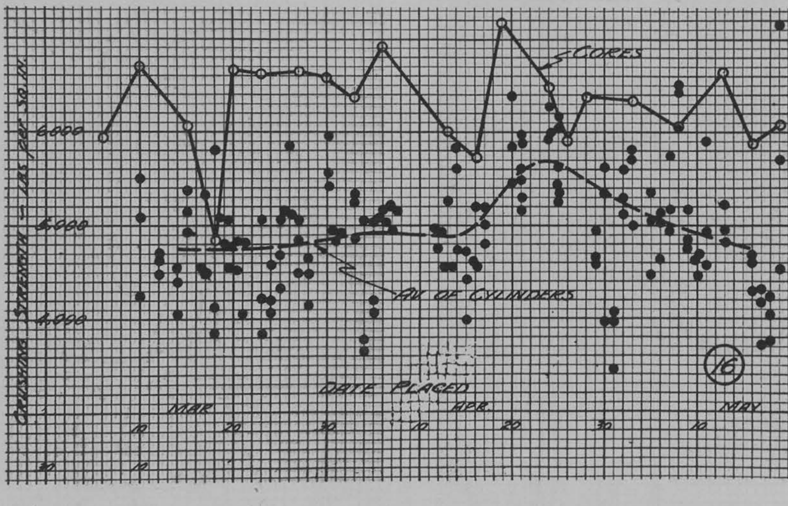
10


CORES
6,000
5,000
4,000
CRUSHING STRENGTH — LBS PER SQ. IN.
AV. OF CYLINDERS
DATE PLACED
16
MAR.
APR.
MAY
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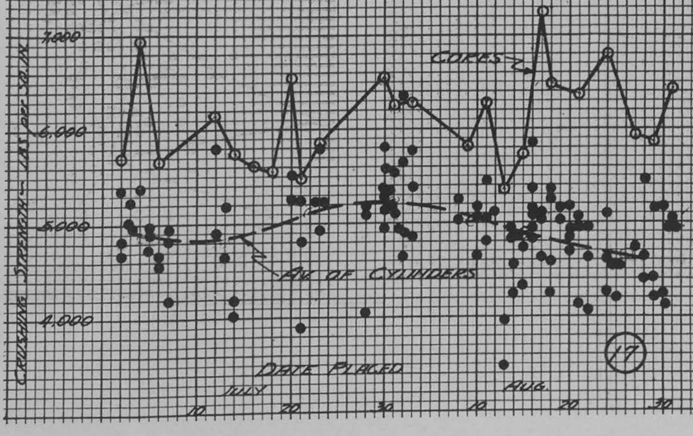
CORES
7,000
6,000
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4,000
CRUSHING STRENGTH — LBS PER SQ. IN.
AV. OF CYLINDERS
DATE PLACED
17
JULY
AUG.
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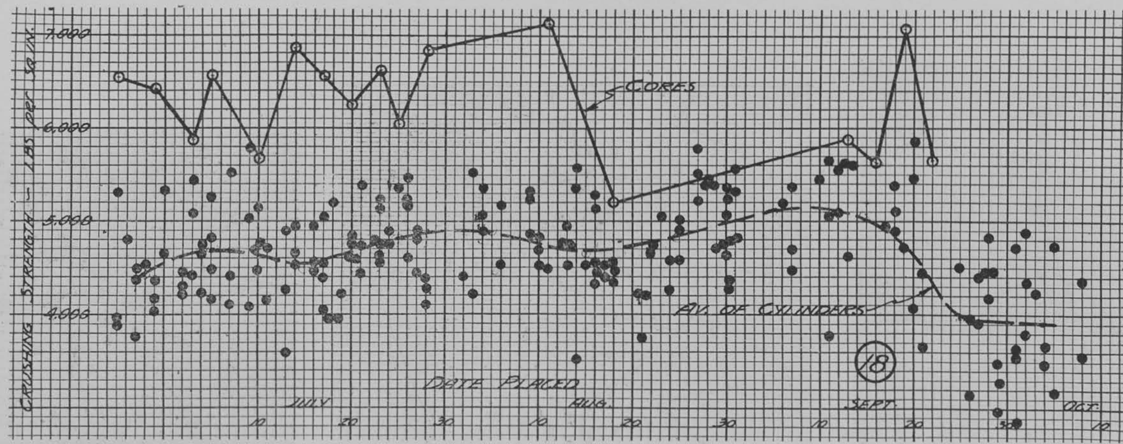
CRUSHING STRENGTH – LBS per SQ.IN.
7,000
6,000
5,000
4,000
CORES
AV. OF CYLINDERS
18
DATE PLACED
JULY
AUG.
SEPT.
OCT.
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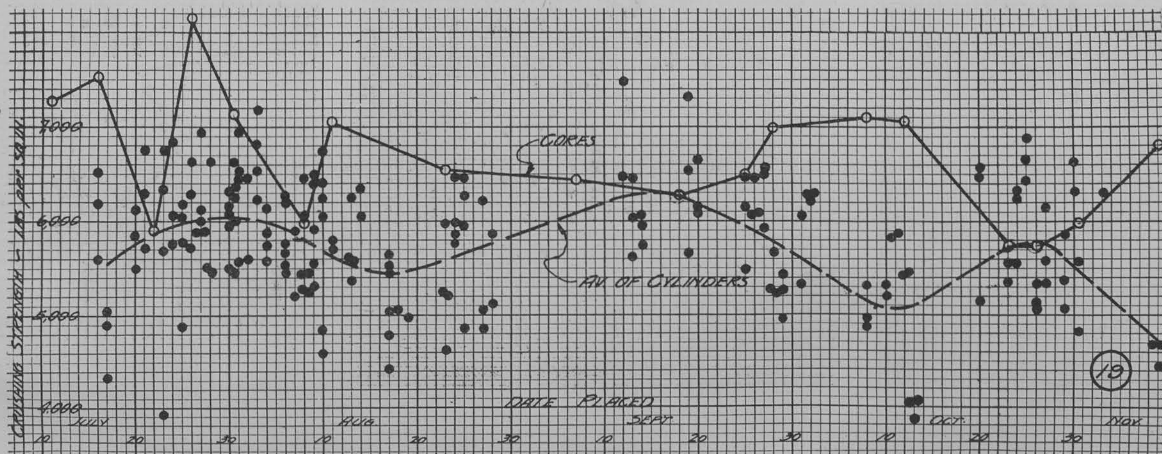
CRUSHING STRENGTH – LBS per SQ.IN.
7,000
6,000
5,000
4,000
CORES
AV. OF CYLINDERS
19
DATE PLACED
JULY
AUG.
SEPT.
OCT.
NOV.
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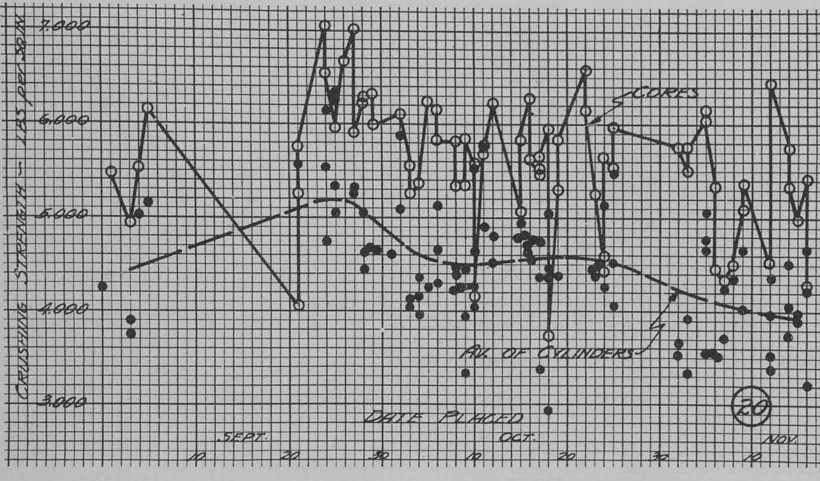
7,000
6,000
5,000
4,000
3,000
CRUSHING STRENGTH ~ LBS. PER SQ. IN.
CORES
AV. OF CYLINDERS
DATE PLACED
SEPT.
OCT.
NOV.
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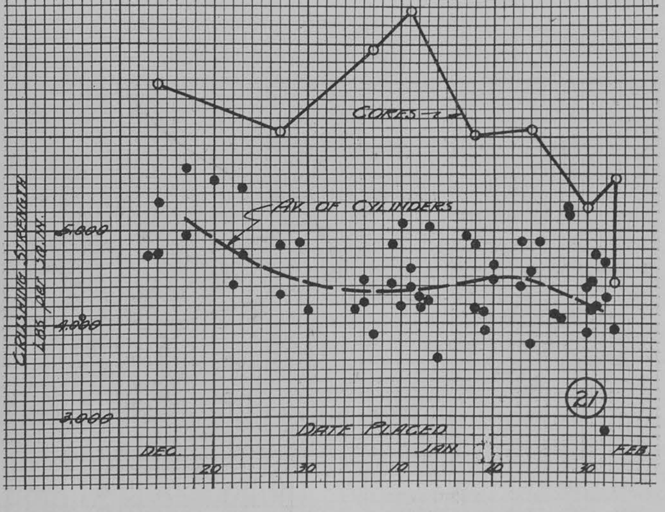
CORES
AV. OF CYLINDERS
5,000
4,000
3,000
CRUSHING STRENGTH
LBS. PER SQ. IN.
21
DATE PLACED
DEC.
JAN.
FEB.
20
30
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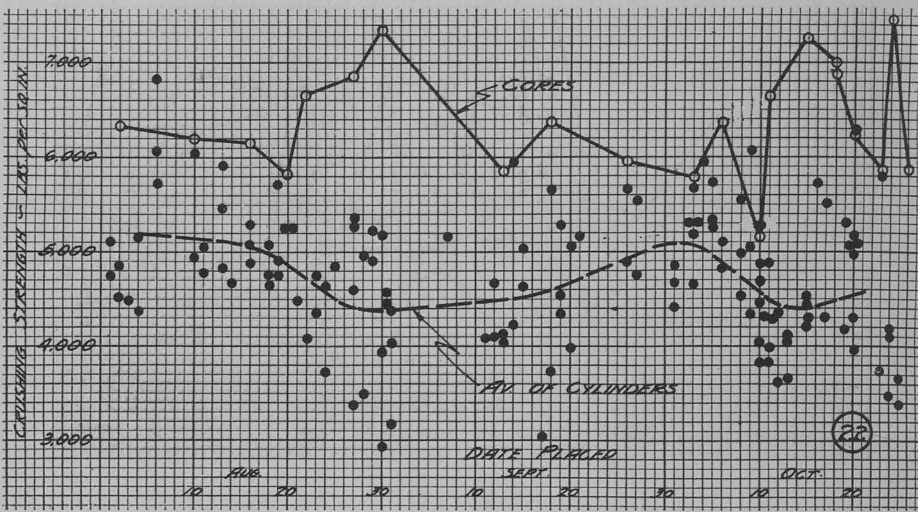

7,000
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3,000
CRUSHING STRENGTH ~ LBS. per SQ. IN.
CORES
AV. OF CYLINDERS
DATE PLACED
AUG.
SEPT.
OCT.
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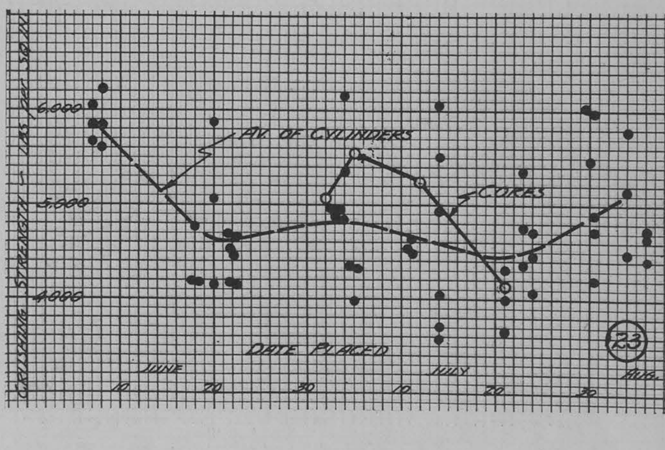
22



6,000
5,000
4,000
CRUSHING STRENGTH ~ LBS. per SQ. IN.
AV. OF CYLINDERS
CORES
DATE PLACED
JUNE
JULY
AUG.
10
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20
30
23

	SUMMARY OF SPECIMENS TESTED										RATIO CORE TO CYL.
	CYLINDERS				CORES						
JOB	NO.	HIGH	LOW	AV.	NO	OLDEST	YOUNGEST	HIGH	LOW	AV.	
1	90	6060	1620	4400	16	157	28	7780	5060	6170	140
2	55	6200	3860	4920	6	229	188	6690	5710	6300	128
3	62	7250	2960	5010	8	106	72	7570	4770	5940	119
4	75	6710	4050	5460	31			6790	4790	5700	104
5	99	5240	2570	3790	30	370	149	7060	2570	5880	155
6	70	7555	4730	6170	13	93	32	6620	4820	5820	94
7	81	6270	3080	4570	10	153	33	7700	4120	5940	130
8	189	7150	3110	4815	40	157	63	6620	3670	5180	108
9	139	6180	2500	3995	30	156	30	5930	3320	4304	108
10	270	7720	4110	5900	22	200	124	7970	5320	6510	110
					11	283	240	7820	5150	6680	113
11	190	6290	1900	4490	24	202	19	7420	3930	5660	126
					12	103	34	6280	3080	4350	119
12	230	6620	2250	4140	28	280	60	6690	3570	4990	121
13	204	6760	2530	4485	30	350	100	7680	4310	6540	146
14	234	6880	2480	4200	35	305	45	8410	3470	5990	143
15	106	6575	3210	5020	15	189	107	7060	4670	6230	124
16	153	7150	3450	4960	21	249	170	7170	4850	6280	127
17	113	6360	3480	4900	24	115	55	7250	5360	6110	125
18	225	5850	2850	4575	17	242	144	7080	5200	6290	137
19	198	7480	3870	5780	18	225	104	8160	5720	6670	115
20	97	6310	2920	4470	70	153	77	7010	3720	5580	125
21	55	5670	2830	4480	15	192	73	7340	3810	6180	138
22	136	6815	2915	4720	21	205	120	7460	5160	6375	135
23	57	6200	3590	4830	5	118	90	6380	4940	5580	115

TABLE I

	SUMMARY OF CYLINDERS											
	% OF CYLINDERS								% OF CYLINDERS WITHIN BAND			
JOB	OVER 10% ABOVE AV.	UNDER 10% BELOW AV.	OVER 15% ABOVE AV.	UNDER 15% BELOW AV.	OVER 20% ABOVE AV.	UNDER 20% BELOW AV.	OVER 25% ABOVE AV.	UNDER 25% BELOW AV.	10% FROM AV.	15% FROM AV.	20% FROM AV.	25% FROM AV.
1	24	22	12	11	8	7	2	6	54	67	85	92
2	24	22	11	13	7	0	2	0	54	76	93	98
3	29	24	19	21	10	10	6	6	47	60	80	88
4	25	13	11	3	5	1	0	1	62	86	94	99
5	17	24	12	15	9	13	6	6	59	73	78	88
6	17	21	7	10	3	3	0	0	64	83	94	100
7	36	38	31	23	21	15	11	10	26	46	64	79
8	13	13	6	8	3	6	3	4	74	86	91	93
9	32	46	27	31	21	19	15	12	22	42	60	73
10	15	18	7	12	2	5	1	2	67	81	93	97
11	33	29	23	21	13	15	9	9	38	56	72	82
12	29	26	20	20	13	16	9	13	45	60	71	79
13	24	27	16	15	11	9	10	5	59	69	80	85
14	28	33	23	24	16	15	12	10	39	53	69	72
15	24	25	15	13	9	7	5	4	51	72	84	91
16	20	20	13	15	7	5	3	2	60	72	88	95
17	11	16	5	7	1	2	1	1	73	88	97	98
18	24	12	14	8	5	6	1	2	64	78	89	97
19	20	17	6	11	2	4	1	2	63	83	94	97
20	23	24	13	15	9	11	5	4	53	72	80	91
21	18	13	11	5	5	2	2	2	69	84	93	96
22	24	24	15	14	10	10	6	5	52	71	80	89
23	28	28	21	12	16	5	5	2	44	67	79	93

TABLE II